



MAARSS

High Temperature Superconductor Coil Expansion Test Using 2G YBCO

Test Day: Friday August 23, 2013

Engineering Design and Development

EP4/Shayne Westover & Coop/Pooja Desai, EP5/Frank Davies

Engineering Test Support

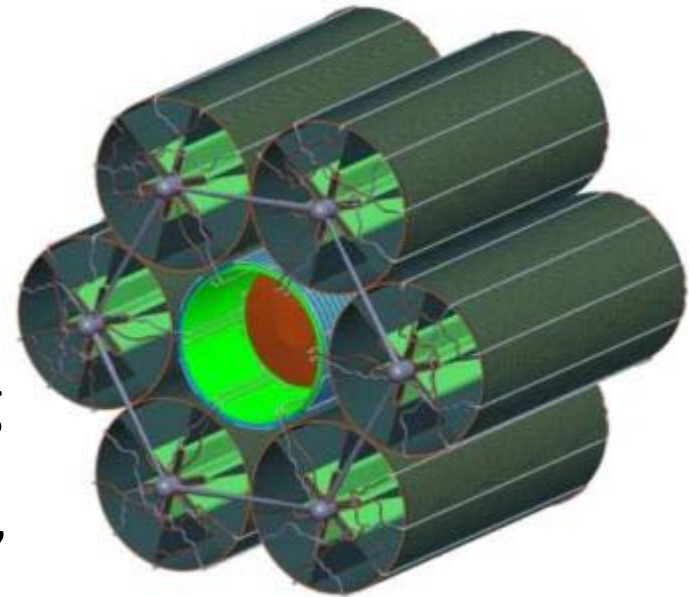
EP6/Cindy Situ, Mike Reddington





Overview of MAARSS project

- **Objective:** Protect humans from space radiation for extended missions in deep space
- **Possible Solution:** Deflect charged particles away from habitat region with high temperature superconducting electromagnets
- Use Lorentz forces to “inflate” or expand the protective shield/coils for a light weight approach



Assembled 6:1 configuration

$$F = q (E + v \times B)$$



Proof of Concept

- Sensitivity testing previously conducted to evaluate superconductor operation and Lorentz forces
- Next test – demonstrate coil expandability





Analysis

- Ran a case on a solenoid and verified results with hand calculations

$$B = u_0 \left(\frac{N}{\sqrt{4R^2 + L^2}} \right) I \text{ (for a solenoid)}$$

- *Where*

B = magnetic field,

u_0 = permeability constant

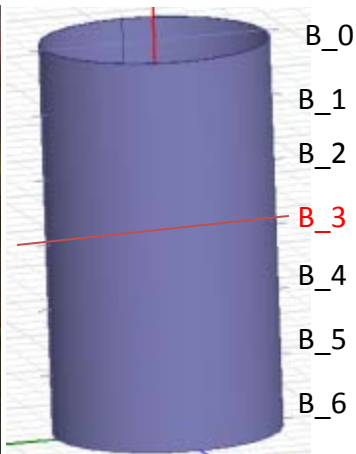
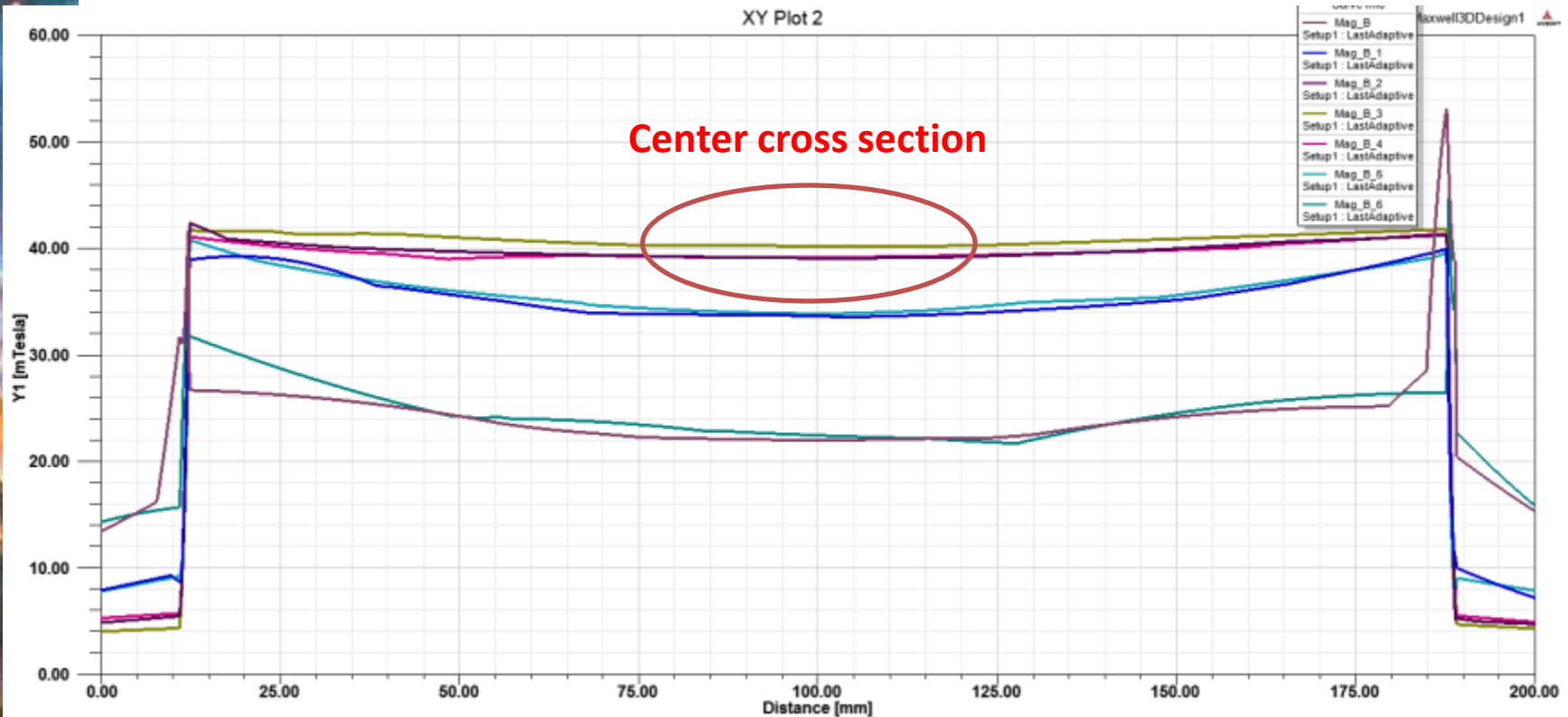
N = number of turns on a solenoid

R = radius of the coil,

L = length of coil,

I = current

Solenoid Case



- *Coil has 47 turns, 120 amps
- *12 inches in length
- *7 inches in diameter
- *Material: copper

Calculated (**center cross section**):

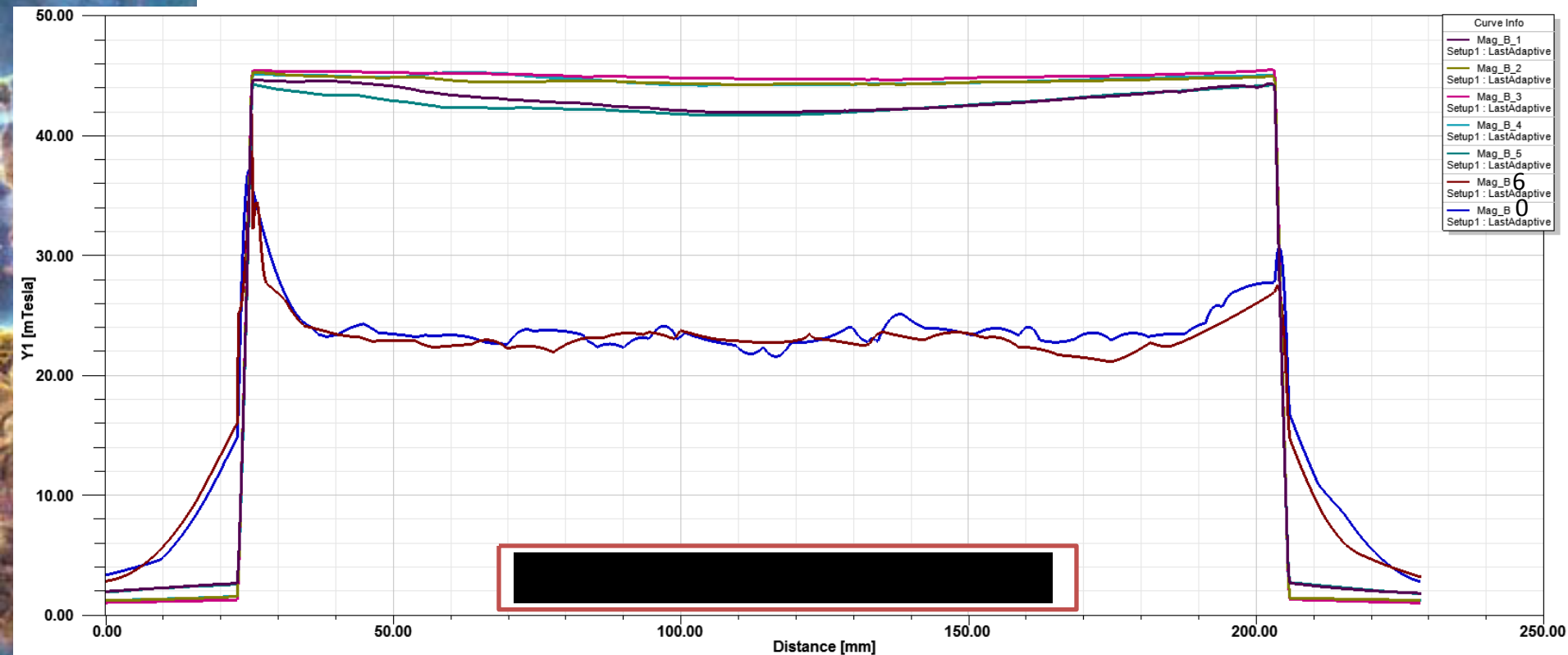
B = 40.017 mTesla, 400.17 G

P_B = 0.0924 psi

Sw analysis: 40.5 mTesla, 405 G

P_B = 0.0946 psi

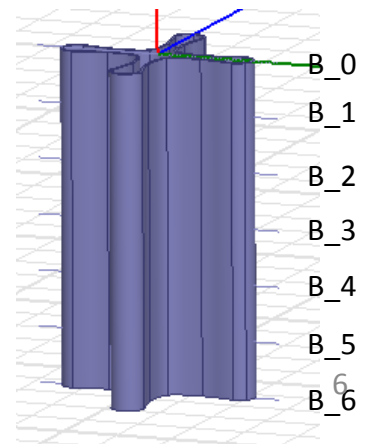
Simulation with Star Shaped Coil



β field is approximately **46 mT (460 G)** in the middle of the Coil (~slightly higher than the cylindrical coil case)

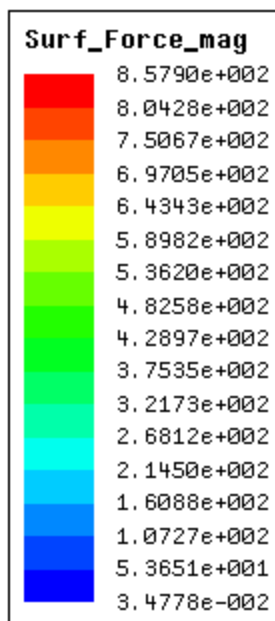
Magnetic pressure would then be around **0.122 psi**.

*120 amp power supplied.





Surface Force Magnitude



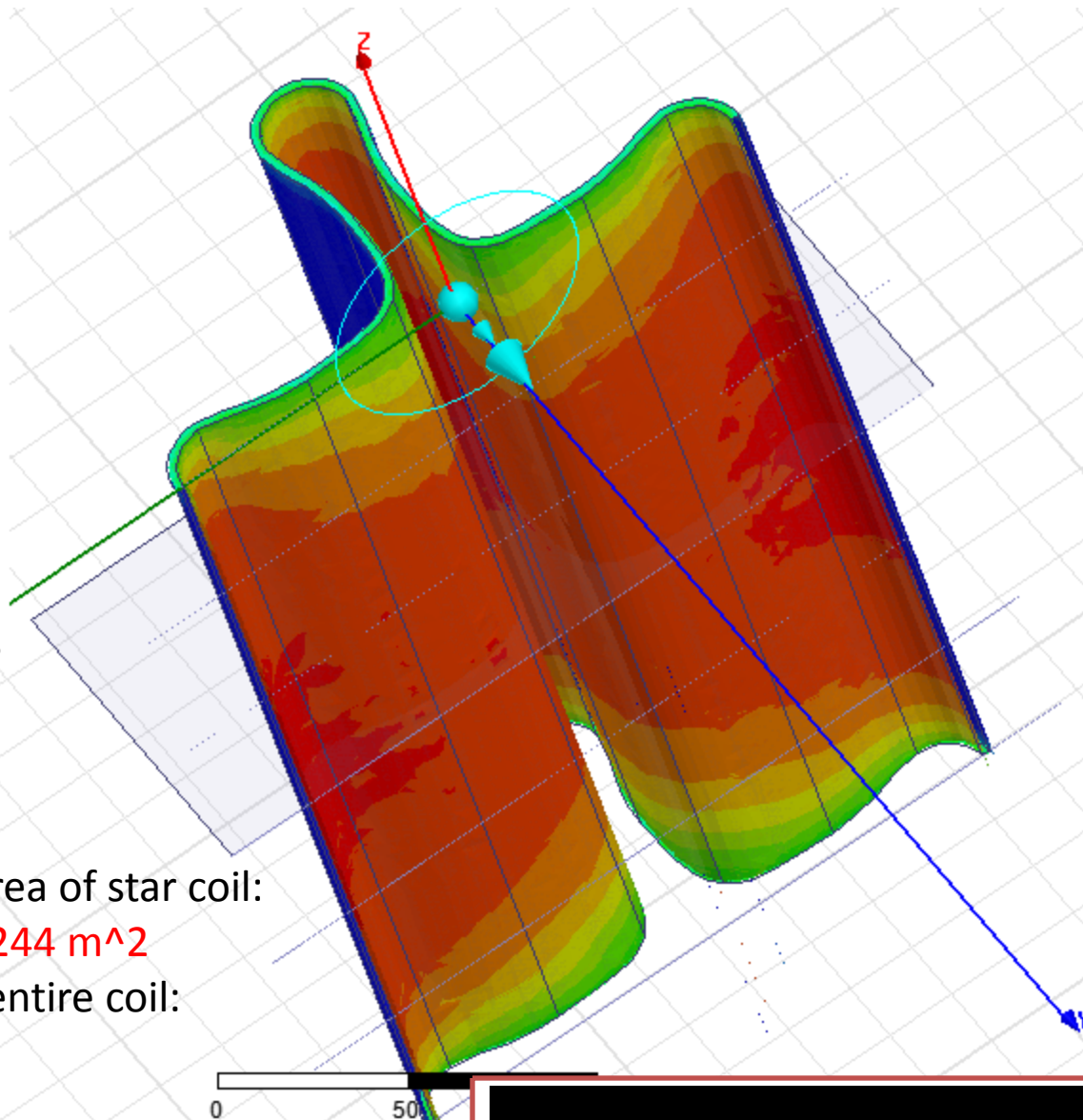
Units: Pascals

Total Surface Area of star coil:

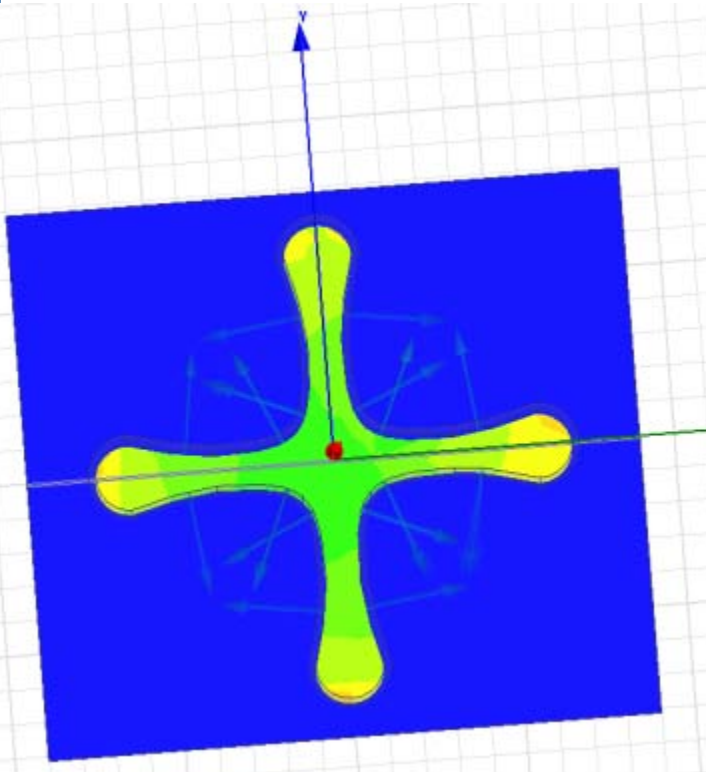
377.5 in² = 0.244 m²

Total Force on entire coil:

< 40 lbs

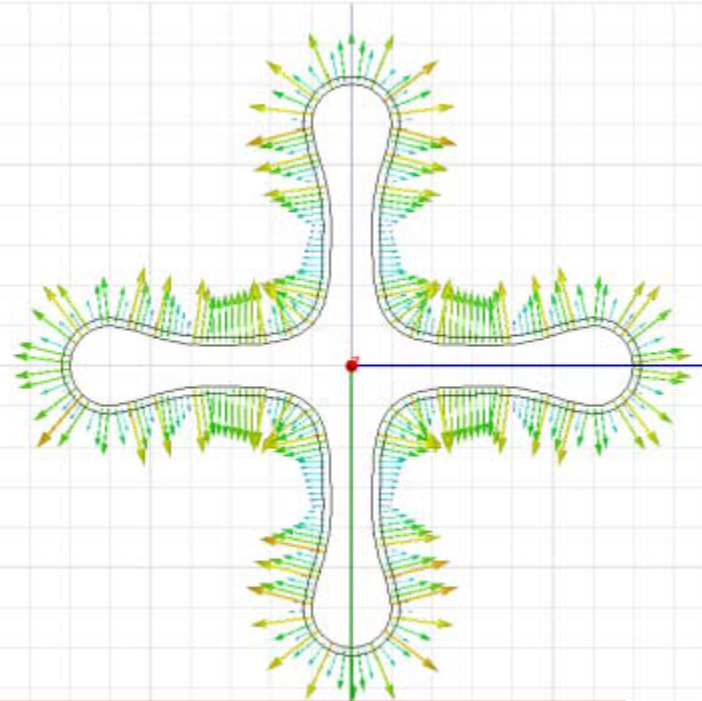


Additional Plots



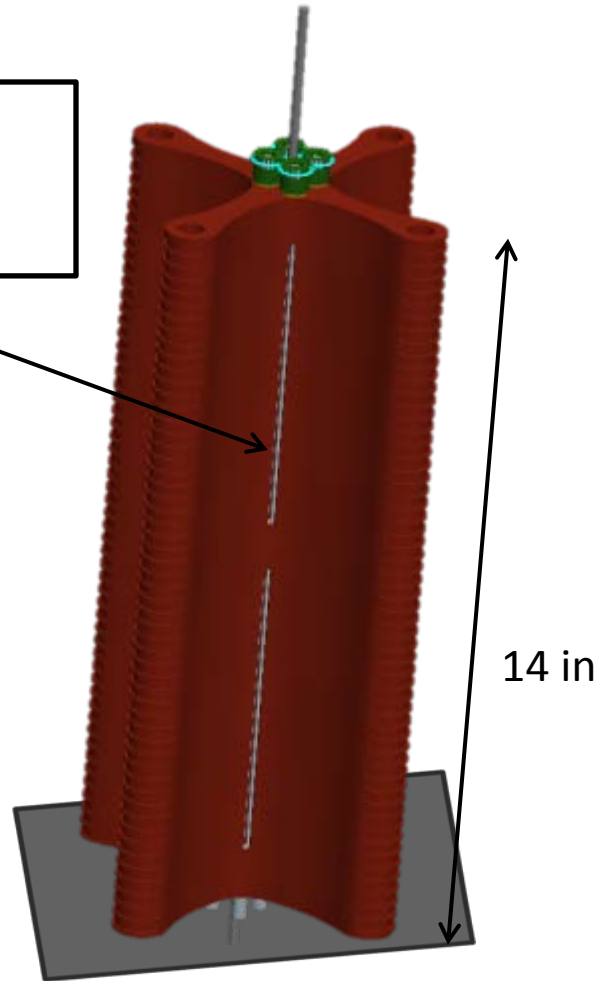
Magnetic Field

Volume Force Density :
 $3 \cdot 10^5 - 6 \cdot 10^5 \text{ N/m}^3$



Assembly

Blankets attached to coil and harness to provide structural stability

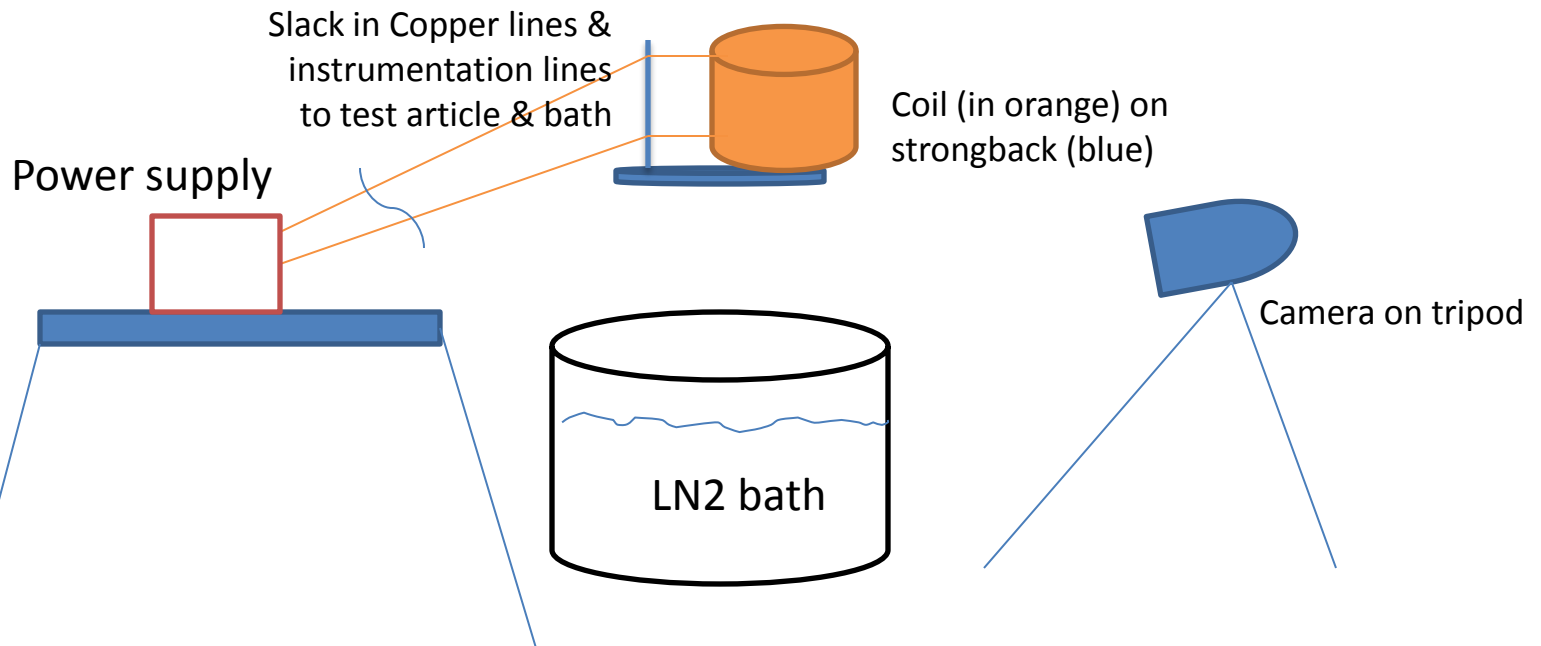
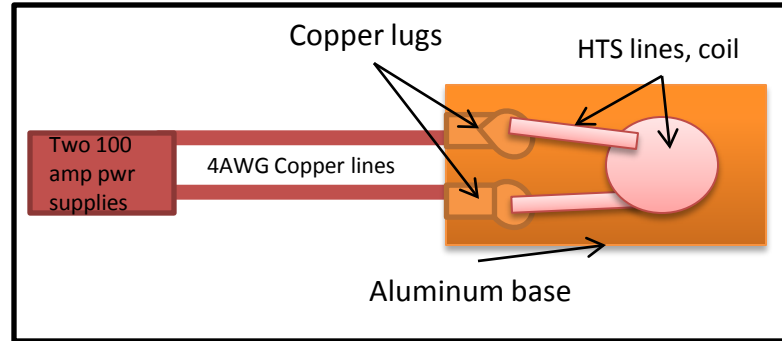


Entire assembly to be dunked in LN2

14 in



Test Setup





Coil Design Specs

- Cylindrical Specs
 - 45 turns (originally designed for 47 turns)
 - 1 turn was lost due to bent superconductor during assembly process
 - 1 turn was lost due to coil to blanket design fitting during assembly
 - Coil length of ~12 inches
 - Star shape (7 inch diameter tip to tip) expanded to 8.75 inches
 - Current increase to 120 amps





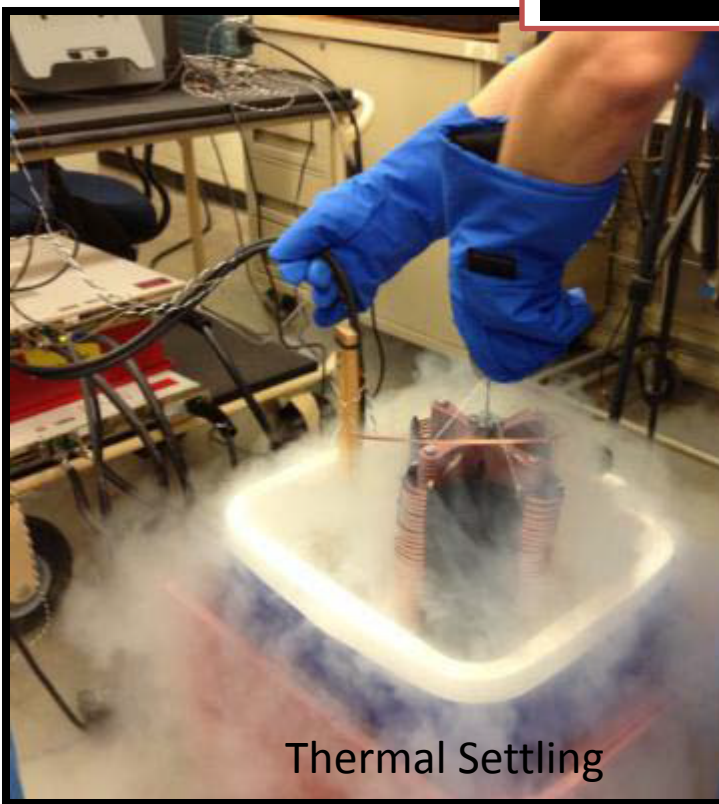
Assembly



Arrival to Test Site



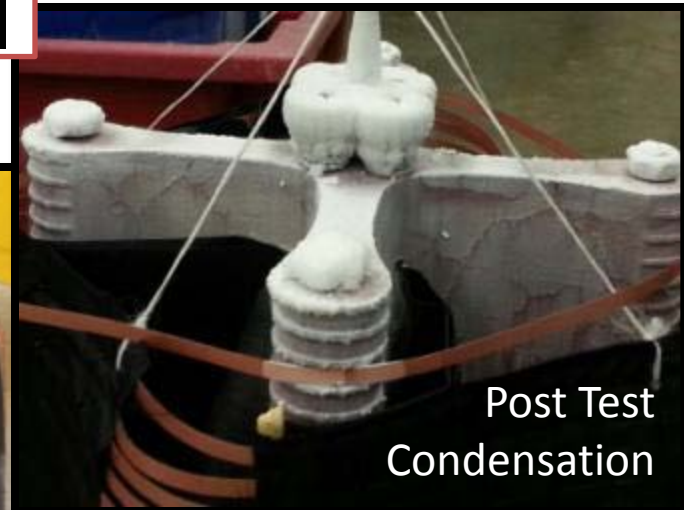
LN2 Bath Refill



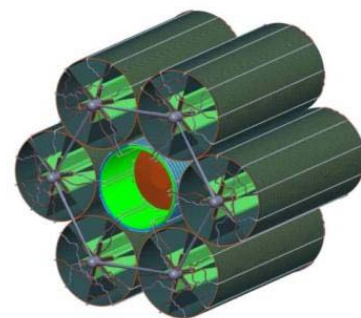
Thermal Settling



Test Complete



Post Test Condensation





Test Results Summary

- Demonstrated the following:
 - Partial coil expansion with 114 amps
 - In place, on the fly coil splice
 - YBCO quench to failure
- Design points to address
 - Mechanical resistances
 - Blanket binding in vertical orientation due to gravity
 - Condensation build up on mechanical parts

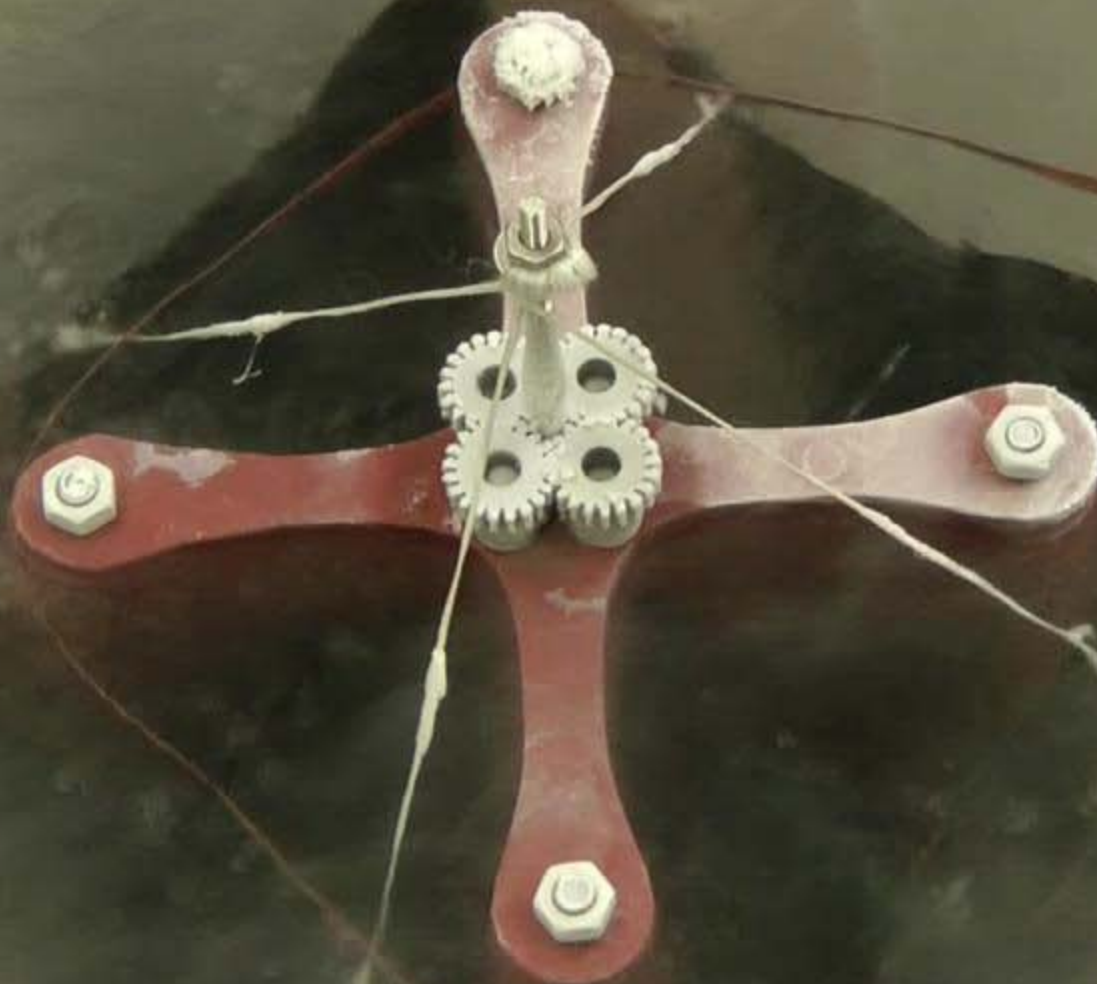
Design modifications required to demonstrate scaled full coil expansion in LN2 and gravity environment



Cycle between the next two slides
to see partial inflation

The third slide following points out the visible changes

20 amps



mm:ss
30:32

114 amps



mm:ss
30:33



Center pole bending
due to no slack in coil
turn 1

Resistance = Bubbles; Tape
failure occurred earlier due
to LN2 boil off past the YBCO
superconductor

Coil contacts lip
on wall during
expansion

LN2 splash noted
due to broad
surface area
motion

Expansion
obvious here.
Motion seen in
multiple locations

Lead wire **turn 1**
becomes taught with
canopy string(s)

mm:ss
30:33

